SPECIFICATION

COMPRESSED SOLID FEED AND COMPRESSED SOLID FEED FORMING APPARATUS

BACKGROUND OF THE INVENTION

Technical Field

The present invention relates to compressed solid feed that can be fed to ruminant mammals, such as cows, goats and deer. The compressed solid feed may be compression formed using fibrous plant materials, e.g. dried hay and corn leaves. More particularly, the present invention relates to compressed solid feed containing desirable amounts of such raw materials having long fibers. Methods and apparatus for making such compressed solid feed are also taught, as well as methods for raising ruminant livestock by feeding such compressed solid feed.

Background Art

Ruminant mammals ingest fibrous food, such as hay, straw and other herbaceous plants. The food is digested while moving from the rumen to the abomasum within the gastrointestinal tract. The rumen is large first compartment of the stomach of a ruminant mammal in which cellulose is broken down by the action of symbiotic microorganisms. The abomasum is the fourth and final true stomach of the rumen. In addition, a ruminant mammal will chew its cud in order to further digest the fibrous food, which is then digested in the respective stomachs and decomposed to smaller units that can be easily absorbed in the gastrointestinal tract.

For a ruminant mammal, complete digestion of cellulose-type food in the rumen is especially important, so that the ruminant mammal can absorb all essential nutrients in the food. For example, propionic acid and acetic acid are produced by fermentation and decomposition of cellulose. If the cellulose is not completely digested, the absorption of these essential nutrients will be low and the animal may have health problems, such as reduced fertility and leg dropsy. Thus, in order to raise

healthy livestock, the animal must eat a sufficient amount of raw feed. Further, the raw feed must stay in the rumen for a sufficient duration so that the cellulose can be properly digested and essential nutrients can be absorbed.

Generally speaking, unprocessed raw hay, straw and other herbaceous plants is usually cut in lengths of about 10 cm before feeding to ruminant mammals, because the animals seem to prefer such lengths. However, known compressed solid feed is prepared using raw hay, straw and herbaceous plants having much shorter lengths.

Compressed solid feed is usually formed with a solid feed forming apparatus (hereafter simply called a forming apparatus) that is specially designed to make solid feed pellets. This type of forming apparatus may include an outer drum, a press wheel eccentrically and rotatably supported in the outer drum and a large number of dies arranged radially around the circumferential face of the outer drum. Using such a forming apparatus, raw materials are successively pushed into hollow spaces disposed within the respective forming dies by movement of a tip end of the press wheel, which is disposed along the circumferential rim of the outer drum. This movement is caused by eccentrically rotating the press wheel so that the raw materials are pushed from a hopper into the outer drum. The raw materials are compressed in the hollow space and the compressed solid feed is discharged through an outlet of the hollow space by repeatedly pushing the press wheel. This compressed solid feed is formed from fibrous materials having short lengths.

The compressed solid feed can be supplied to the animal using an automatic feeding apparatus, which improves the efficiency of feeding the animals. However, if livestock only eat the known compressed solid feed, health problems have sometimes occurred. That is, even if the ruminant animal eats a sufficient amount of the known compressed solid feed, the animal still may not obtain sufficient nutrition from the known compressed solid feed, because it is not completely digested.

DISCLOSURE OF THE INVENTION

It is, therefore, one object of the present invention to provide improved compressed solid feed and methods and apparatus for making compressed solid feed,

as well as methods of raising livestock.

According to a study performed by the inventors, known compressed solid feed does not stay in the rumen for a sufficient duration to allow complete digestion, because the length of the raw materials in the solid feed is too short. The inventors also found that this problem can be solved by providing compressed solid feed having fibers of appropriate lengths. Moreover, such compressed solid feed can be mixed with other feed to form a blended feed that provides sufficient nutrition so that it becomes unnecessary to also feed unprocessed hay or other raw fibrous plant materials to the animal.

For example, in one aspect of the present teachings, the compressed solid feed includes fibrous plant materials, e.g. dried hay, straw and other herbaceous plants, having lengths of at least 3 cm. Further, the content of such dried hay, straw and other herbaceous plant is preferably at least 20% of the total weight of the compressed solid feed. The content preferably also may be within a range of 20-40%, and more preferably between 20-30%. Optionally, the length of the dried hay, straw and other herbaceous plants that are used as the fibrous plant materials in the compressed solid feed may between about 3 to 7 cm.

In another aspect of the present teachings, the content of such dried hay, straw and other herbaceous plant having lengths of at least 3 cm is at least about 40% of the total weight of the compressed solid feed, more preferably at least 50% of the total weight and even more preferably, between about 55-80% of the total weight.

In another aspect of the present teachings, the compressed solid feed may optionally have a density of between about 0.4 to 0.6 and more preferably between about 0.45 to 0.55.

Compressed solid feed of the present teachings stays in the rumen of the ruminant livestock for a sufficiently long duration in order to be more completely digested and adsorbed, because appropriate amounts of long fibers are included in the compressed solid feed. Therefore, healthy livestock can be raised using such compressed solid feed.

Methods of producing compressed solid feed are also taught. A

representative example includes preparing a raw material comprising at least 60% by weight of fibrous plant materials having lengths of at least 3 cm. The raw material is then compressed in a compressed solid feed forming apparatus to form compressed solid feed. This apparatus may include, for example, dies having raw material receiving spaces and plungers positioned opposite to inlets of the raw material receiving spaces. After disposing the raw materials in the raw material receiving spaces, the raw materials may compressed by moving the dies relative to the plungers along the axial or longitudinal direction between the inlets and outlets of the raw material receiving spaces, thereby forming the compressed solid feed.

In addition, the fibrous plant materials having lengths of 3 cm or longer length may be mixed with the other raw materials prior to disposing the raw materials in the compressed solid feed forming apparatus. In the alternative, the two sets of materials may be separately placed in the compressed solid feed forming apparatus and the solid feed forming apparatus may mix these materials.

As noted above, preferably about 40% by weight of the raw materials having lengths of 3 cm or longer are utilized in these methods.

Blended feed for ruminant livestock may also be prepared. Preferably, the blended feed includes the compressed solid feed containing fibrous materials having lengths greater than 3 cm and the compressed solid feed is at least 15% of the total weight of the blended feed.

In another aspect of the present teachings, methods of raising livestock or producing livestock product may include feeding the livestock the above-described blended feed. By preparing a blended feed based upon the compressed solid feed and other feed, the blended feed can be distributed to the animals using an automatic feeding machine. Because the fibrous plant materials in the compressed solid feed can be properly digested in the rumen to provide proper nutrition, it is not necessary to feed the animals any other cellulose-based feed. Thus, it is not necessary, for example, to manually distribute raw unprocessed hay or other cellulose-based feed to the animals and the feeding can be performed completely automatically. As a result, manual labor to feed the animals is significantly reduced and livestock can be raised

more cheaply and efficiently.

Further, compressed solid feed forming apparatus are taught. In one aspect, the apparatus has a die with raw material receiving spaces and these raw material receiving spaces may have a tapered shape, in which the inlet opening has a wider surface area than the outlet side. The raw material receiving spaces receive the raw materials, which preferably includes a portion of fibrous plant materials having a length of at least 3 cm. A pushing rod may be installed opposite to the inlet of each raw material receiving space and may be adapted to compress the raw materials by reciprocally moving either one of or both of the die and the pushing rod along the axial direction between the inlet and an outlet of the raw material receiving space. Thus, the pushing rod will move relative to the die in the direction (in the pushing direction) from the inlet to the outlet of the raw material receiving spaces. The pushing rods will push in and out the raw material receiving spaces to compress the raw materials disposed between the pushing rod and the raw material receiving spaces.

Because this apparatus is adapted to push the raw materials, the moving direction of the pushing rod and the direction of compressing the raw materials are aligned. Therefore, the raw materials are not significantly squeezed and cut between the die and the pushing rod in the step of pushing the raw materials to the raw material receiving spaces. Therefore, the ratio of the raw materials in the compressed solid feed maintaining the desired length (about 3 to 7 cm) after compression can be considerably increased.

Additionally, the raw material receiving space may be tapered in various shapes. For example, the raw material receiving space may be so formed as to be a rectangular tapered raw material receiving space having a rectangular cross-section and the higher height on the inlet side than the outlet side. The raw material receiving space may also have a cylindrical shape. Further, the raw material receiving space also may have a conical or pyramidal shape in which the inlet side has a longer length and the wider transverse width than the outlet side. In the latter case, it is preferable to continuously install a straight pipe part with no change of the cross-section shape

in the outlet side of the raw material receiving space.

A plurality of raw material receiving spaces may be arranged in parallel and a plurality of pushing rods may be arranged opposite to the respective raw material receiving spaces in the forming apparatus. Such a forming apparatus is capable of efficiently producing a plurality of types of compressed solid feed having the desirable properties described above and below.

Additional objects, features and advantages of the present teachings will be readily understood after reading the following detailed description together with the accompanying drawings and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side view of a compressed solid feed forming apparatus according to a first representative embodiment.

FIG. 2 is a plan view of the solid feed forming apparatus according to the first representative embodiment.

FIG. 3 is a vertical cross-sectional view of a raw material receiving space.

FIG. 4 is a transverse cross-sectional view a raw material receiving space.

FIG. 5 a perspective view of the compressed feed forming portion of a second representative compressed solid feed forming apparatus.

MODES FOR PRACTICING THE INVENTION

Compressed solid feed may be formed by compressing various types of fibrous plant materials, such as dried plant stalks and leaves. For example, the plant stalks and leaves that can be used for the solid feed of the present invention may be stalks and leaves of hay, straw and herbaceous plant products, all of which may be used without any specific limitation. Typical examples of hay include Timothy grass, alfalfa, Sudan grass, oat hay and other types of hay. Typical examples of the herbaceous plant products include true grass straw, oats, sorghum, barley, corn and other similar plants.

For example, corn stalks and leaves may be utilized, and more preferably

immature corn stalks and leaves may be utilized. In this case, the term "immature" means that the crop has not completely ripened and the stalks and leaves are not yet mature.

"Plant stalks and leaves" and "fibrous plant materials" are generally intended to mean plant raw materials that mainly contain stalks and/or leaves of plants. While other plant components may be utilized, preferably the majority of the raw materials are stalks and/or leaves of plants. Thus, preferred compressed solid feed mainly contains the stalks and leaves of such plants as the main components, but naturally may further contain other raw materials.

The shapes of the preferred compressed solid raw materials are not specifically limited and may include, for example, a cylindrical bale shape and a rectangular prism-like cubic shape. The cubic shape is preferable. A layered body, a sheet-like body or a plate-like body is more preferable.

The preferred compressed solid feed may be separated into layered bodies and sheet-like bodies. Because it can be separated, the feed assumes a sheet-like state when given to the animal, which state is an original state of the plant stalks and leaves. Therefore, the compressed solid feed may provide improved taste, chewing properties and digestion for the livestock.

Also, the size of the solid feed is not especially limited. On the other hand, the cross-section surface area vertical to the direction of the compression at the time of solidification is preferably between about 3 cm × 3 cm to 4 cm × 8 cm. Further, the compressed solid feed preferably has a cross-section surface area that is less than 10 cm × 10 cm.

When the cross-section surface area is between about 3 cm × 3 cm to 4 cm × 8 cm and the thickness is between about 0.3 cm to 3 cm, the compressed solid feed is particularly useful for blending with other feed in order to make a blended feed. With such sizes, the compressed solid feed can be evenly blended with the other feed and the ruminant livestock will eat the solid feed eaten together with the other feed. More preferably, the thickness of the solid feed is between about 0.3 cm to 1.5 cm.

Finely cut plant stalks and leaves may also be contained in the compressed

solid feed. However, plant stalks and leaves having a length of at least 2.5 cm are preferably at least 10% of the total weight of the compressed solid feed. With the length and the content within such ranges, the compressed solid feed will remain in the rumen for a sufficient duration. More preferably, the length and the content of the plant stalks and leaves are at least 2.5 cm and at least 20% by weight, respectively. Further, plant stalks and leaves having a length of at least 3 cm are preferably at least 20% by weight of the total weight of the compressed solid feed.

In one aspect, the weight of the fibrous plant materials having lengths of at least 3 cm is between about 20-40% (preferably less than 40%), more preferably between 20-35% and even more preferably, between 20-30%, of the total weight of the compressed solid feed. In these cases, the length range of plant stalks and leaves is preferably between about 3 cm to 7 cm. If plant stalks and leaves having a length of at least 3.0 cm are at least 20% of the total weight of the compressed solid feed, ruminant mammals (especially cattle and cows) can be exclusively fed a blended feed containing the compressed solid feed and no other cellulose-based feed is required.

In another aspect, plant stalks and leaves having a length of at least 3 cm are preferably at least 40% by weight of the total weight of the compressed solid feed, more preferably 50% or higher and most preferably between about 55% to 80%. Again, the length range of plant stalks and leaves is preferably between about 3 cm to 7 cm.

In this specification, the length of the plant stalks and leaves generally means the length of the plant stalks and leaves in a longitudinal direction. Further, the ratio of the plant stalks and leaves in the compressed solid feed having the desired length can be calculated in the following representative manner. After forming and weighing the compressed solid feed, it is broken down to recover the plant stalks without cutting the plant stalks and leaves, which plant stalks and leaves are then sorted based on length. For example, the sort is performed by using a sieve to separate the plant stalks and leaves of the broken solid feed according to mesh size. Thus, the mesh size may be 3 cm and the plant stalks and leaves that remain in the mesh after separation have a length of at least 3 cm. Thereafter, the weight of the sorted plant

stalks and leaves is measured and compared to the total weight of the solid compressed feed that was used to determine the weight ratio. Thus, the ratio (the weight ratio) of plant stalks and leaves having the defined length or longer, as utilized in this specification, is the ratio of the measured weight of the plant stalks retained in the sieve compared to the total weight of the compressed solid feed that was used.

Preferably, the compressed solid feed has a density (g/cm^3) between about 0.4 to 0.6. If the density is within the defined range, the compressed solid feed retains its shape during transportation and the animal can easily chew the compressed solid feed. If the density is less than 0.4, the compressed solid feed may easily break during transportation. Further, if the solid feed breaks before mixing with other feed, the broken solid feed becomes difficult to evenly mix and the livestock do not prefer to eat this broken solid feed. Moreover, the length of the stalks and leaves sometimes is shortened by this breakage.

On the other hand, if the density exceeds 0.6, it may become difficult for the livestock to roughly pulverize (i.e. chew) the compressed solid feed. Therefore, the inventors have found that the livestock do not prefer to eat compressed solid feed having a high density. Further, if such solid feed is mixed in a blended feed, the difference between the solid feed and the other feed becomes noticeable to the livestock and the livestock may not eat such blended food. The density is, therefore, more preferably between about 0.45 to 0.55 g/cm^3. This density range provides relatively durable compressed solid feed during transportation, but relatively soft compressed solid feed for chewing by the livestock.

While the water content of the compressed solid feed is not specifically restricted, it is preferably 8% (hereafter % by weight) or higher, because the solid feed will easily break when the water content is less than 8%. The water content is more preferably between about 10% to 12%.

The compressed solid feed may be fed to ruminant livestock solely or together with other feed to form a blended feed. In this specification, blended feed is intended to mean feed which contains previously mixed base feed and raw feed and does not require other raw feed such as hay. In other words, the present compressed solid feed

may be used solely or as solid feed of a blended feed or circulated and supplied while being mixed with blended feed. Thus, the compressed solid feed is preferably used either as one component of a blended feed or by itself.

If the solid feed has a cross-section surface area between about 3 cm × 3 cm to 4 cm × 8 cm and the thickness is between 0.3 cm to 3 cm, and more preferably between 0.3 cm to 1.5 cm, it is quite suitable for use as a solid feed in a blended feed. The compressed solid feed is preferably fed to dairy cows or beef cattle, although the present compressed solid feed and methods and apparatus may be easily utilized to make compressed solid feed for other animals.

In blended feed for ruminant livestock, preferably 30 to 50% by weight of the total weight of the blended feed is fibrous components and more preferably 40 - 50%. Preferably, at least 4% by weight of the total weight of the blended feed comprises fibrous plant materials having a length of at least 2.5 cm (preferably at least 3.0 cm) supplied by the present compressed solid feed. More preferably, at least 5% of the total weight of the blended feed comprises fibrous plant materials having a length of at least 3.0 cm supplied by the present compressed solid feed. This blended feed may preferably be fed to dairy cows and/or beef cattle.

A representative method for producing the solid feed of the present invention will now be described below. The solid feed may be produced by compressing the above-described plant stalks and leaves. The hay and the herbaceous products used as raw materials are, for example, cut into stalks and leaves after harvesting and then sorted. In many cases, only the stalks are cut to prevent the stalks from being finely powdered. The leaves and stalks produced in such a manner are dried and mixed to provide raw materials for the compressed solid feed.

The raw materials preferably contain between 10%-12% water. If the water content is less than 10%, it becomes difficult to form the compressed solid feed. If the water content is higher than 12%, too much steam is generated during compression and it becomes difficult to harden the raw materials after forming.

Preferably, plant stalks and leaves having lengths 3 cm or longer are at least 60% of the total weight of the raw materials that form the compressed solid feed, more

preferably at least 70% and further preferably at least 80%. On the other hand, plant stalks and leaves having lengths shorter than 3 cm are preferably 40% or lower and more preferably 30% or lower and furthermore preferably 20% or lower.

The plant stalks and leaves may be dried, cut and processed in such a manner to form desired shapes by compression forming. The below-described compressed solid feed forming apparatus may be preferably utilized with this method. Naturally, the compressed solid feed may preferably have the above-described desirable shapes and also the above-described preferred densities may be utilized.

A representative compressed solid feed forming apparatus preferably includes at least one die having raw material receiving spaces. A plunger is preferably positioned opposite to an inlet of each raw material receiving space. Thus, plant stalks and leaves are compressed inside of the raw material receiving spaces by moving the die and/or the plunger along an axial line between the inlet and an outlet of the raw material receiving space. By compressing the raw materials in such a manner, the plant stalks and leaves are not substantially ruptured or cut during compression. Thus, the length of the plant stalks and leaves is maintained during the compression step and the compressed solid feed preferably contains raw materials having the above-described preferred lengths.

Preferably, the inlet of the raw material receiving space has an opening that is wider than the opening of the outlet. In that case, rupturing and cutting of the plant stalks and leaves can more effectively be prevented. Also, a guide portion is provided adjacent to the inlet of the raw material receiving space along the axial direction. This guide portion may guide the plant stalks and leaves into the raw material receiving space. Preferably, the opening area of the guide portion inlet is larger than the opening area of the inlet of the raw material receiving space. By providing such a tapered guide portion and pushing the plant stalks and leaves in order to fill the guide portion towards the outlet of the raw material receiving space using the plunger, one unit of compressed solid feed can be formed at the outlet of the raw material receiving space. The plant stalks and the leaves packed in a tapered state within the guide portion and the raw material receiving space are gradually formed by compressing at

the narrowest opening area. Consequently, the compressed solid feed can be formed by pushing the plant stalks and leaves using uniform pushing conditions. Thus, the intermediate pushing operation within the guide portion does not significantly affect the final product and the lengths of the plant stalks and leaves can easily be maintained in the final product.

Naturally, one unit of the compressed solid feed may be formed by each compression operation. For example, the compressed solid feed may be formed by compressing the outer edge the plant stalks and leaves packed in the raw material receiving space so as to almost completely fill the raw material receiving space. The next unit of compressed solid feed is thus formed in the next successive pushing operation. Thus, the next unit of compressed solid feed is closely attached to the rear end face of the previously formed unit of compressed solid feed. In such a manner, a plurality of solid feed units are discharged out of the raw material receiving space in the order in which the units were formed. These units are attached at the boundaries of each unit. A block of the solid feed units can be easily divided along the respective boundaries formed by the respective pushing operations.

Further, the cross-sectional area of the raw material receiving space preferably has an opening size larger than the length of the plant stalks and leaves. Practically, if the plant stalks and leaves are preferably at least 3 cm, the opening size of the raw material receiving space is also preferably at least 3 cm, even in the smallest cross section part of the raw material receiving space.

Compressed solid feed having the preferred densities can be obtained by adjusting the amount of the plant stalks and leaves that are supplied into the raw material receiving space. In addition, the shape and the length of the raw material receiving space and the pushing force of the plunger and other similar parameters can be adjusted to change the density.

Preferably, the compressing step does not reduce the ratio of the plant stalks and leaves having length greater than 3 cm to less than 40% of the total weight of the compressed solid feed. Immediately after compressing, the plant stalks and leaves (solid matter) generally reach a temperature as high as 95 to 100°C and will be

relatively soft. The solid matter in such state can be hardened by rapidly cooling and drying. The solid matter is pushed out of the raw material receiving space by moving the plunger. After being pushed out, the solid matter is then subjected to a cooling and drying process, in which the solid matter is cooled and dried until the water content reaches a preferable level.

Naturally, these methods can provide the preferred compressed solid feeds described above in further detail.

Thus, the present teachings provide, for example, the following advantageous properties:

(1) Compressed solid feed that may contain plant stalks and leaves (raw fibrous materials) having lengths of at least 3 cm in 20% or more by weight of the total weight of the compressed solid feed.

(2) Compressed solid feed according to description (1), in which the compressed solid feed has a density between about 0.4 to 0.6 g/cm^3.

(3) Blended feed for ruminant livestock produced by blending the above compressed solid feed with other feed components, in which the compressed solid feed is preferably at least about 15% of the total weight of the blended feed.

(4) Blended feed according to the description (3), wherein the compressed solid feed has a density between about 0.4 to 0.6 g/cm^3 and more preferably between about 0.45 to 0.55 g/cm^3.

(5) Blended feed according to the description (3), wherein the solid feed has a cross-sectional surface area size of between 3 cm × 3 cm to 4 cm × 8 cm and a thickness between about 0.3 to 3 cm.

(6) Compressed solid feed comprising a portion of plant stalks and leaves having a length of at least 3 cm and having a cross-section surface area size of 3 cm × 3 cm or wider and 4 cm × 8 cm or narrower and a thickness of between about 0.3 to 3 cm.

Representative examples of the present teachings will now be described in further detail with reference to the attached drawings. This detailed description is merely intended to teach a person of skill in the art further details for practicing

preferred aspects of the present teachings and is not intended to limit the scope of the invention. Only the claims define the scope of the claimed invention. Therefore, combinations of features and aspects disclosed in the following detail description may not be necessary to practice the invention in the broadest sense, and are instead taught merely to particularly describe some representative examples of the invention. Moreover, various features of the representative examples may be combined in ways that are not specifically enumerated in order to provide additional useful embodiments of the present teachings.

A first representative compressed solid feed forming apparatus (hereafter called "solid feed forming apparatus 1") is illustrated in FIGS. 1 to 4. FIGS. 1 and 2 illustrate the entire solid feed forming apparatus 1 of the present example. In the drawings, reference numeral 2 denotes the main base on which an electric motor 3, reduction gears 4, a crank mechanism part 5 attached to the output shaft 4a of the reduction gears 4, and a forming part 6 operated by the crank mechanism part 5 are disposed.

The output of the electric motor 3 is transmitted to the reduction gears 4 by a belt 7. The reduction gears 4 may constructed using any conventional structure that provides a desired speed reducing ratio, preferably using the ratio of the gear teeth in a row of gears. No particular design is required for the first representative embodiment. The tip end portion of the output shaft 4a of the reduction gears 4 may be, for example, supported by bearings 4b so to be adapted to rotate relative to the base 2.

The crank mechanism part 5 may have an eccentric disk 8 that is eccentrically attached to the output shaft 4a of the reduction gears 4. A crank arm 9 may be attached to the eccentric disk 8. The eccentric disk 8 may be fixed so that the eccentric disk is offset by a desired size relative to the output shaft 4a of the reduction gears 4. A circular supporting part 9a of the crank arm 9 may be rotatably supported on the outer circumference of the eccentric disk 8. The end portion of the crank arm 9 may be fixed to the rear end of a slide bar 20 of the forming part 6 by a supporting shaft 20a in a manner so that the end portion can rotate up and down relative to the forming part

6.

The forming part 6 may have respective front and rear dies 21, 22 comprising a plurality of substantially cylindrical raw material receiving spaces 21a, 22a (also called forming spaces 21a, 22a), which are adapted to receive the raw materials. A plurality of pushing rods 23, 24 may be positioned between dies 21, 22 and opposite to the respective substantially cylindrical raw material receiving spaces 21a, 22a of dies 21, 22.

Dies 21, 22 are joined and supported at a constant interval from each other and adapted to reciprocate back and forth (in the right and left directions as shown in the figures.). More specifically, slide bars 26, 27 are installed in parallel to each other along the longitudinal direction and on the upper face of a sub-base 25, which is mounted on the main base 2. Both ends of the respective slide bars 26, 27 may be firmly supported by respective brackets 26a, 26a, 27a, 27a. Dies 21, 22 may be installed so as to form a bridge between both slide bars 26, 27 (up and down in the FIG. 2).

The number of forming spaces in dies 21, 22 are not particularly limited. In the first representative example, six forming spaces 21a, 22a are shown for purposes of illustration. The respective forming spaces 21a, 22a may all have the same shape and are disposed within the respective dies 21, 22. Forming spaces 21a of the front side die 21 and forming spaces 22a of the rear side die 22 are preferably arranged symmetrically in the longitudinal direction. As shown in FIGS. 3 and 4, the respective substantially cylindrical raw material receiving spaces 21a, 22a may include guiding parts 21aa, 22aa and forming parts 21ab, 22ab. The respective guiding parts 21aa, 22aa may be oppositely disposed along the longitudinal direction. As shown in FIG. 1, slide bar 20 may be installed so as to bridge both dies 21, 22 and may be disposed along the center longitudinal axis.

As shown in FIG. 2, pushing rods 23, 24 may be supported on the main base 2 by supporting stands 28, 29 along the axial direction. Preferably, pushing rods 23, 24 are between the inlets and the outlets of the respectively corresponding substantially cylindrical raw material receiving spaces 21a, 22a and are inserted into

the inlets.

As shown in FIGS. 3 and 4, the sides of the guiding parts 21aa, 22aa receive the pushing rods 23, 24, which are inserted into the inlets of the respective forming parts 21a and 21b. After pushing the raw materials within the respective substantially cylindrical raw material receiving spaces 21a, 22a, the compressed solid feed is discharged through forming parts 21ab, 22ab, which serve as outlets for the final product.

Preferably, the forming parts 21ab, 22ab of the respective substantially cylindrical raw material receiving spaces 21a, 22a have a tapered shape and the inlet side is wider than the outlet side.

As shown in FIG. 3, the compressed solid feed forming portion 22 may have a rectangularly tapered shape with a rectangular cross-section shape, in which H1 > H2. Height H1 represents the diameter of the inlet side (the right end side of the drawing) and height H2 represents the diameter of the outlet side (the left end side of the drawing).

As shown in FIG. 4, the width W of the forming part 22ab is preferably the same for both the inlet side and the outlet side. Additionally, the guiding parts 21aa, 22aa may have an approximately pyramidal shape in which the height and the width of the inlet side are larger than the outlet side. Naturally, FIGS. 3 and 4 illustrate one representative raw material receiving space 22a of the die 22 and the other respective forming empty parts 21a of the die 21 also may have the same shape.

As illustrated in FIG. 1, raw materials may be placed into hopper 30, which is preferably disposed above dies 21, 22. Two supporting ports 31, 32 may support the lower part of the hopper 30. The front side supporting port 31 may be positioned above the rear face of the front side die 21 and the rear side supporting port 32 may be positioned above the front face of the rear side die 22.

In the solid feed forming apparatus 1 of the first representative embodiment, the output shaft 4a of the reduction gears 4 rotates at an appropriate speed by supplying power to the electric motor 3 and subsequently eccentrically rotating the eccentric disk 8. Because the center of the eccentric disk 8 eccentrically rotates about

the outlet shaft 4a, the circular supporting part 9a of the crank arm 9 also rotates around the output shaft 4a while rotating on the circumferential face of the eccentric disk 8. Consequently, the crank arm 9 provides a cranking movement. A recess 2a may be formed in the upper face of the main base 2 so that the circular supporting part 9a does not interfere with the crank arm 9 during operation.

Due to the crank movement of the crank arm 9, dies 21, 22 will reciprocate back and forth along the slide bars 20. The hopper 30 also moves together with both dies 21, 22. On the other hand, because the pushing rods 23, 24 are fixed to the main base 2, they do not move. Therefore, the pushing rods 23, 24 are pushed in and out the respective substantially cylindrical raw material receiving spaces 21a, 22a of the dies 21, 22.

The operation state illustrated in FIGS. 1 and 2 will not be described in further detail. When the crank arm 9 is withdrawn to the furthest position, dies 21, 22 reach the furthest retracted position and the respective front side pushing rods 23 are inserted into the front side of substantially cylindrical raw material receiving spaces 21a. Thus, the raw materials are pushed into the forming parts 21ab of the respective substantially cylindrical raw material receiving spaces 21a, thereby compressing the raw materials. On the opposite side, the respective rear side pushing rods 24 are withdrawn from the rear side substantially cylindrical raw material receiving spaces 21a, and separate by an appropriate distance to form gaps between the rear side die 22 and the rear side pushing rods 24. Therefore, raw materials can be supplied into the gaps from the supporting port 32 formed in the rear side of the hopper 30.

Although not specifically illustrated in the figures, the rods 23, 24 and the dies 21, 22 naturally can be reciprocally moved to form compressed solid feed within raw material receiving spaces 22a. For example, when the crank arm 9 reaches the advanced end, the rear side pushing rods 24 are pushed into the respective rear side substantially cylindrical raw material receiving spaces 22a. Therefore, the raw materials that were supplied into the gaps between the rear side die 22 and the rear side pushing rods 24 are pushed in the respective substantially cylindrical raw material receiving spaces 22a and are thereby compressed. Further, the front side

pushing rods 23 are withdrawn from the front side substantially cylindrical raw material receiving spaces 21a and separate by an appropriated distance to form a gap between the front side pushing rods 23 and the substantially cylindrical raw material receiving spaces 21a. Therefore, additional raw materials are supplied into the gaps by the supporting port 31 in the front side of the hopper 30.

As a result, dies 21, 22 reciprocate back and forth in the longitudinal direction by the crank movement of the crank arm 9 and subsequently the raw materials are repeatedly and reciprocally pushed into the substantially cylindrical raw material receiving spaces 21a, 22a. Therefore, raw materials are packed into all the substantially cylindrical raw material receiving spaces and are compressed. The compression-formed and solidified raw materials (solid feed) are gradually pushed out of the outlet side by being pushed from the inlet side.

In one representative example that is particularly preferred for making feed for dairy cattle, the following raw materials G may be supplied to the solid feed forming apparatus 1. For example, corn plant stalks and leaves maybe utilized and the stalks and leaves may be cut and sorted into stalks and leaves. Preferably, the raw stalks were cut into lengths between about 3 to 6 cm in length so as to prevent the stalks from being pulverized and dried in the sun. The leaves were also dried in the sun. After drying, the stalks and the leaves are mixed. A preferred blending ratio is as follows:

The length of the plant stalks and leaves	wt.%
Shorter than 1 cm	2.0
Longer than or equal to 1 cm and shorter than 3 cm	20.9
Longer than or equal to 3 cm	77.1
Total	100%

Before compression, the weight of the plant stalks and leaves were immersed in water for 1 hour, dried, classified by length and weighed in order to obtain this weight percentage data.

Solid feed obtained by supplying this preferred set of raw materials into solid

feed forming apparatus 1 have the following characteristics. The compressed solid feed has a prism-like shape with a cross-section surface area of about 3.5 cm × about 7.5 cm and a thickness of approximately 3.5 cm. In order to determine the weight percentage of respective portions in the final product formed using the above-described preferred set of raw materials, the compressed solid feed was immersed in water for 1 hour, broken apart, collected with a net and then dried. The resultant plant stalks and leaves were sorted and classified by length corresponding to the lengths of the plant stalks and leaves in each portion. Thereafter, each portion was weighed. The measurement results were as follows:

The length of the plant stalks and leaves	wt.%
Shorter than 1 cm	9.5
Longer than or equal to 1 cm and shorter than 3 cm	33.2
Longer than or equal to 3 cm	57.3
Total	100%

According to these results, 25.7% of plant stalks and leaves that initially had a length of greater than 3 cm were pulverized or cut during compression and shortened to less than 3 cm. However, 55 % or more of plant stalks and leaves having lengths greater than 3 cm were retained, thereby forming a solid feed having excellent taste and digestion properties. This solid feed also can be easily blended with other feed and the cattle ate the blended food without a particular preference for the solid feed or the other feed in the blend.

The first representative solid feed forming apparatus 1 compresses the raw materials G by pushing and pulling the respective pushing rods 23, 24 in and out of the substantially cylindrical raw material receiving spaces 21a, 22a. At the same time, dies 21, 22 reciprocate in the axial direction between the inlets and the outlets of the substantially cylindrical raw material receiving spaces 21a, 22a. Consequently, the raw materials are pushed into the respective substantially cylindrical raw material receiving spaces 21a, 22a. The direction of the relative movement of the pushing rods

23, 24 and the direction of pushing the raw materials (the direction along the axial lines of the inlets and the outlets of the substantially cylindrical raw material receiving spaces21a, 22a) are aligned. Therefore, the raw materials are not substantially squeezed and cut between the dies 21, 22 and the pushing rods 23, 24 when the raw materials are pushed into the substantially cylindrical raw material receiving spaces 21a, 22a. As a result, the ratio of raw materials having a length of about 3 to 6 cm in the final product formed by this compression technique can be increased.

In comparison, in the known art, only about 7% of the raw materials maintained a length of about 3 to 6 cm after compression. On the other hand, more than 50% of the raw materials maintained the desired length using the first representative solid feed forming apparatus 1. Thus, the present teachings provide compression methods and apparatus that are substantial improvement over the known art.

Additionally, various modifications may be made to the first representative solid feed forming apparatus without departing from the spirit of the present teachings. For example, the first representative example utilizes pushing rods 23, 24 fixed to the main base 2 and both dies 21, 22 reciprocate to perform the relative pushing movement of the pushing rods 23, 24. In the alternative, the solid feed forming apparatus may include pushing rods 23, 24 that are adapted to directly reciprocate to provide pushing movement of the pushing rods 23, 24.

Further, the first representative solid feed forming apparatus pushes the raw materials G between the proceeding end and the recess end of the crank arm 9 by arranging two sets of dies 21, 22 and pushing rods 23, 24 in the longitudinal direction. However, the apparatus may be constructed with a single die and a set of pushing rods to compress the raw materials G.

A second representative embodiment 40 is illustrated in FIG. 5 and includes the same crank mechanism part 5 as the first representative embodiment. However, a different forming part 40a is utilized that may include a pair of a dies 42 provided with a plurality of substantially rectangular raw material receiving spaces 41. A plurality

of pushing rods 43 may be disposed opposite to the respective substantially rectangular raw material receiving spaces 41. Unlike the apparatus of the first embodiment, one pair of pushing rods 43 is directly reciprocated within the respective substantially rectangular raw material receiving spaces 41 .

Further, a sub-base 44 is fixed on the upper face of a main base (not illustrated) and the die 42 is fixed in a rear part of the upper face of the sub-base 44. Five rows of substantially rectangular raw material receiving spaces 41 are formed along the lateral direction of the upper and lower portions of die 42. Each raw material receiving space 41 preferably may have a rectangular tapered shape with a rectangular cross-section and the inlet side is preferably wider than the outlet side. This latter feature is the same as the first representative embodiment.

Raw material loading chambers 45 are formed in front of the respective rows of the substantially rectangular raw material receiving spaces 41. A hopper 46 for retaining raw materials is attached to the upper sides of the five rows of raw material loading chambers 45. Five rows of rectangular window portions 45a are formed in the upper and lower two stages in the lateral direction and correspond to the respective substantially rectangular raw material receiving spaces 41. The pushing rods 43 are inserted into the respective raw material loading chambers 45 through the rectangular window portions 45a.

Similar to the first embodiment, the pushing rods 43 are installed in the rear face of a supporting stand 47 that reciprocally moves (in the right and left directions in the drawing) due the pushing movement provided by electric motor 3, reduction gears 4, and crank mechanism part 5. In addition, similar to the first embodiment, the supporting stand 47 is attached to the tip end of the crank arm 9 of the crank mechanism part 5.

Five rows of pushing rods 43 are installed along the lateral direction in upper and lower stages, so as to correspond to the respective substantially rectangular raw material receiving spaces 41 and window portions 45a. The rows of pushing rods 43 are preferably fixed so as to project behind and in parallel to one another toward the respective substantially rectangular raw material receiving spaces 41.

The solid feed forming apparatus 40 of FIG. 5 may be operated by supplying power to the electric motor 3, whereby the supporting stand 47 will reciprocate due to the movement provided by the reduction gears 4 and the crank mechanism part 5. When the supporting stand 47 moves backward, the respective pushing rods 43 are inserted into the substantially rectangular raw material receiving spaces 41 through the respective window portions 45a. By pushing the pushing rods 43 into the substantially rectangular raw material receiving spaces 41, the raw materials G that are disposed in the raw material loading chambers 45 are pushed in the substantially rectangular raw material receiving spaces 41 and compressed. Further, when the supporting stand 47 moves forward, all the pushing rods 43 are pulled out the substantially rectangular raw material receiving spaces 41 and then withdrawn from the raw material loading chambers 45. When the respective pushing rods 43 are pulled out of the raw material loading chambers 45, raw materials (not shown in the figure) disposed in hopper 46 are supplied to the respective raw material loading chambers 45.

The supporting stand 47 is repeatedly reciprocated while raw materials are supplied from the raw material loading chambers 45. Thus, the raw materials are repeatedly pushed into the substantially rectangular raw material receiving spaces 41 from the raw material loading chambers 45 and compressed. Finally, the compressed solid feed is pushed through the outlet side (the rear face side of the die 42) of the substantially rectangular raw material receiving spaces 41.

The solid feed forming apparatus 40 of the second representative embodiment is also adapted to compress raw materials by reciprocating the pushing rods 43 along in the axial direction between the inlets and the outlets of the substantially rectangular raw material receiving spaces 41, thereby pushing the raw materials G into the substantially rectangular raw material receiving spaces 41. The movement direction of the pushing rods 43 and the pushing direction of the raw materials are aligned with each other. Therefore, unlike known apparatus, the raw materials are substantially prevented from being squeezed and cut in the pushing step. Therefore, the ratio of the raw materials which maintain the desired length (about 3 to 6 cm) in the compressed

solid feed can be significantly increased.

Needless to say, various modifications may be made to the substantially rectangular raw material receiving spaces 41 as described further above. For example, in the first and second representative embodiments, electric motor 2 supplies driving movement to the crank mechanism part 5 in order to reciprocate the dies 21, 22 (or the pushing rods 23, 24). However, a hydraulic cylinder or a rack and pinion mechanism may be utilized to provide the reciprocating movement.

Furthermore, in addition to or instead of corn stalks and leaves, Timothy grass, Sudan grass, alfalfa, true grass straw, oats stalks and leaves, sorghum stalks and leaves, barley stalks and leaves, and hay may be used as the raw materials.

Finally, the raw material receiving portions naturally may have cross sections other than rectangular or cylindrical.

In order to determine the usefulness of the compressed solid feed produced according to the description above, a comparative test was performed. Two groups of cows were selected and compressed solid feed of the present invention was fed to one group and the other group was fed according to conventional feeding techniques.

The cows in group A were feed two types of compressed solid feed according to the present teachings. The first type of compressed solid feed consisted of compressed oat hay in which 20% of the total weight of the compressed solid feed was oat hay having a length of between 3 cm to 7 cm. The second type of compressed solid feed consisted of compressed alfalfa hay in which 10% of the total weight of the compressed solid feed was alfalfa hay having a length of between 3 cm to 7 cm. Both of these compressed solid feeds were prepared with a rectangular cross-section of 3.5 cm X 7 cm. These two types of compressed solid feed were mixed with other feed materials (i.e., steamed and rolled corn, pellets, cotton seed, beet pulp) such that the oat hay compressed solid feed was 22% of the total weight of the blended feed, the alfalfa hay compressed solid feed was 15% of the total weight of the blended feed and the other materials were 63% of the total weight of the blended feed. The cows of group A were not feed any other feed materials, such as unprocessed cellulose-based feed.

The cows of group B were fed (1) "Mrs. Pine" blended feed which is commercially available from CHUBU SHIRYO Co., Ltd. and includes dried pineapple residue, steamed and rolled corn and other non-cellulose based feed materials and (2) raw unprocessed oat hay having a length of about 10 to 30 cm. "Mrs. Pine " blended feed was 65 % of the total weight of the feed given to the animals and unprocessed oat hay was the remaining 35 % of the total weight of the feed.

Eleven cows were in group A and 9 cows were in group B. The feed given to the cows of group A was distributed using an automatic feeding machine. Therefore, it was much more convenient to feed the cows of group A than the cows of group B, because the raw uncompressed oat hay can not be automatically distributed and must be distributed by hand, thereby requiring more manual labor to distribute the feed. The cows of group A were fed 5 times a day using the automatic feeder and the cows of group B were manually fed 4 times a day. For the cows of group B, the raw uncompressed oat hay was distributed 30 minutes after distributing the Mrs. Pine blended feed. On the other hand, the blended feed given to the cows of group A was pre-mixed and included both the compressed solid feed and the other feed materials.

After birthing calves, the cows of each group were fed the respective feed for 1 year. During this time, the cows were milked three times a day and the composition of the milk from each group was determined. Over the course of the year, the cows of group A had an average daily milk output of 23.1 kg/day, whereas the cows of group B had an average daily milk output of 23.5 kg/day. The milk fat of group A was 3.97%, whereas the milk fat of group B was 4.15%. Finally, the non-fat milk solids in the milk of the cows of group A and B were 9.0 and 9.18%, respectively.

Thus, these results demonstrate that there was no difference between the cows of group A and B. Therefore, the compressed solid feed of the present invention provides good nutrition and healthy cows. Moreover, because the compressed solid feed can be distributed to the cows more easily than raw, uncompressed fibrous materials, efficiency is greatly increased. Thus, the present compressed solid feed can be utilized to provide improved and more efficient methods of feeding livestock, because the feed can be distributed to the livestock solely using automatic feeding

machines.